N94-33639

EXERCISE WITH PREBREATHE APPEARS TO INCREASE PROTECTION FROM DECOMPRESSION SICKNESS

Preliminary Findings [as of 1 August 1993]

James T. Webb, Ph.D., Michele D. Fischer, B.S., Cristine L. Heaps, M.A., and Andrew A. Pilmanis[1], Ph.D.

KRUG Life Sciences Inc., San Antonio, TX
[1] Armstrong Laboratory, Brooks AFB, TX

ABSTRACT

Extravehicular activity (EVA) from the space shuttle involves one hour of prebreathe with 100% oxygen, decompression of the entire Shuttle to 10.2 psia for at least 12 hours, and another prebreathe for 40 min before decompression to the 4.3 psia suit pressure. We are investigating the use of a one-hour prebreathe with 100% oxygen beginning with a ten-minute strenuous exercise period as an alternative for the staged decompression schedule described above. The 10-min exercise consists of dual-cycle ergometry performed at 75% of the subject's peak oxygen uptake to increase denitrogenation efficiency by increasing ventilation and perfusion. The control exposures were preceded by a one-hour prebreathe with 100% oxygen while resting in a supine position. The twenty-two male subjects were exposed to 4.3 psia for 4 hours while performing light to moderate exercise. Preliminary results from 22 of the planned 26 subjects indicate 76% DCS following supine, resting prebreathe and 38% following prebreathe with exercise. The staged decompression schedule has been shown to result in 23% DCS which is not significantly different from the exercise-enhanced prebreathe results. Prebreathe including exercise appears to be comparable to the protection afforded by the more lengthy staged decompression schedule. Completion of the study later this year will enable planned statistical analysis of the results.

INTRODUCTION

To avoid the serious threat of DCS symptoms developing during EVA from the Space Shuttle in a 4.3 psia pressure suit, some form of denitrogenation is required. Denitrogenation prior to direct decompression from 14.7 psia requires at least 3.5 hours of resting prebreathe to achieve DCS protection comparable to that provided by the current staged decompression method of denitrogenation (Waligora et al., 1984). The staged decompression schedule involves decompression of the entire Shuttle to 10.2 psia for at least 12 hours, requires a total of 1.67 hours of 100% oxygen prebreathing, and results in problems such as reduced instrument cooling capacity at 10.2 psia. The staged decompression is preferable because it requires less prebreathing time immediately prior to EVA. Development of less time-consuming prebreathe procedures which provide comparable protection from severe venous gas emboli (VGE; precordial Doppler grades 3 and 4) and DCS while allowing decompression directly from 14.7 psia to 4.3 psia would improve efficiency of EVA operations.

Efficiency of denitrogenation and protection from DCS can be increased by including negative pressure breathing (Balldin and Borgstrom, 1977), warm environmental conditions (Balldin, 1973), warm water immersion (Balldin and Lundgren, 1972), or various forms of exercise (Vann, 1989; Balke, 1954; Webb et al., 1943) during the prebreathe period. We are investigating the use of a ten-minute strenuous exercise period at the beginning of a one-hour, 100% oxygen prebreathe as a means of enhancing denitrogenation by increasing ventilation and perfusion while avoiding exercise-induced fatigue (Webb et al., 1989, 1993).

METHODS

Twenty-two male subjects were exposed to a pressure of 4.3 psia for 4 hours while performing moderate exercise. The prebreathe conditions consisted of 60 min of prebreathing 100% oxygen, beginning with (or without, as a control) 10 min of dual-cycle ergometry performed at 75% of the subject's peak oxygen uptake (Heaps et al., 1993). The resting portion of each prebreathe was accomplished in the supine position. Subjects were monitored for VGE using a Hewlett-Packard SONOS 1000 Echo Imaging System and observed for DCS symptoms. The endpoints were completion of the 4-hour exposure or development of Grade 2 DCS joint pain or any other DCS symptoms. The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

RESULTS

The experiment is currently 85% completed, and final statistical evaluation awaits completion of control and test exposures on all 26 subjects. To date, the incidence of any DCS following exercise-enhanced prebreathe with 100% oxygen is 36% versus 77% after resting prebreathe (N = 22). DCS symptoms disappeared during repressurization to ground level in all eight subjects experiencing DCS following exercise-enhanced prebreathe. Symptoms included joint pain, headache, paresthesia, and hot/cold flashes. During the exposures following a one-hour resting prebreathe, two incidents of respiratory DCS (chokes) occurred, one of which continued to be evident at ground level. That subject was treated with hyperbaric oxygen therapy resulting in complete resolution of symptoms.

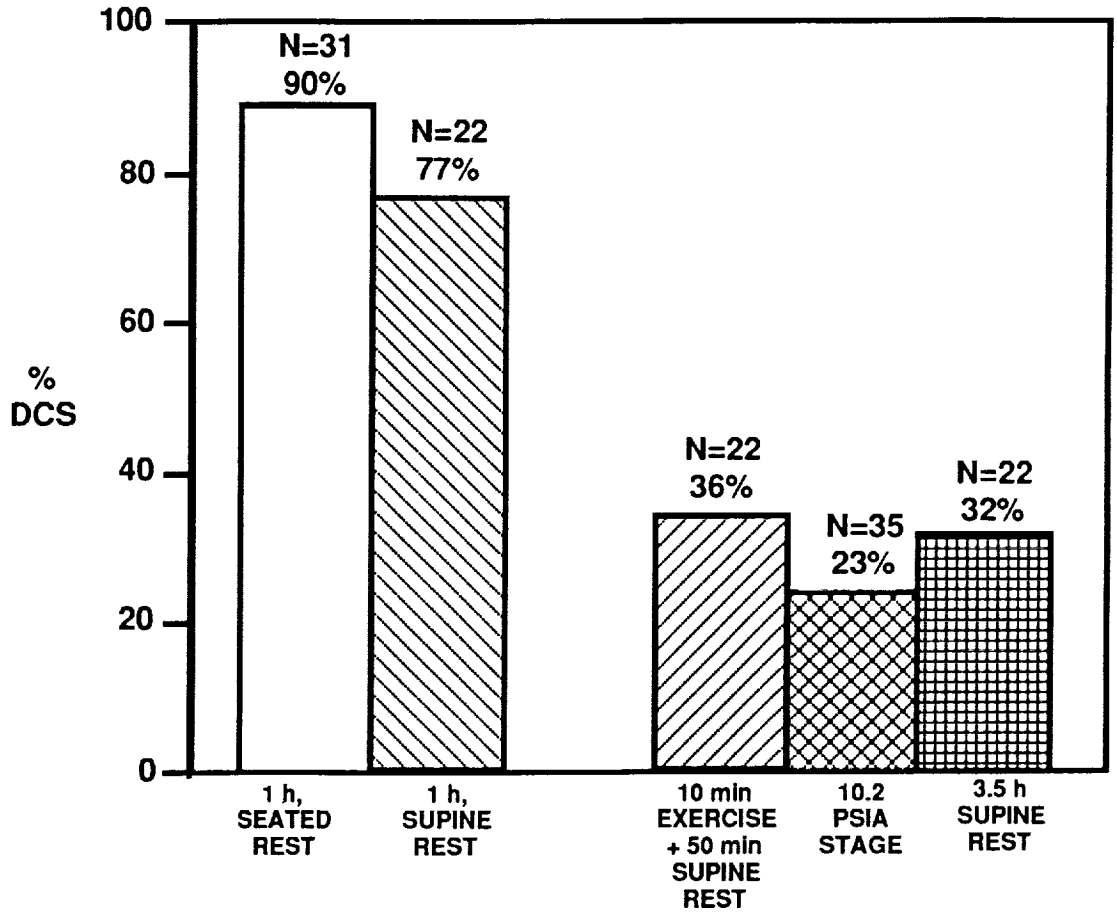

Figure 1: COMPARISON OF DCS INCIDENCE

DISCUSSION

We compared the incidence of DCS during the test (exercise-enhanced prebreathe) and control (resting prebreathe) exposures to data from previous experiments where length of 100% oxygen prebreathe and pressure of exposure were identical and where exercise during exposure was similar. A study accomplished at the USAF School of Aerospace Medicine in the 1980s used a seated one-hour prebreathe and less energetic exercises at altitude. As seen in Figure 1, the incidence of any DCS symptoms following 1 h of resting prebreathe, seated or supine, was not different. The subjects in the current study therefore appear to be equivalent in DCS susceptibility with subjects who participated in the earlier study.

When the incidence of DCS symptoms in the current study test exposures, exercise-enhanced one-hour prebreathe, is compared with the incidence of symptoms in a study examining past and current Shuttle EVA prebreathe procedures (Waligora et al., 1984), the difference is not significant. We caution that these data are preliminary and that completion of the remaining subjects could negate the findings reported here.

The method of obtaining data on VGE occurrence during the study by Waligora et al. (1984) did not involve the more sensitive capabilities of echo-imaging in addition to Doppler ultrasound used during the current study. Comparison of VGE incidence and levels could be affected by the differences in these methods.

Some indicators of exposure severity based on VGE (time to development of any VGE, time to development of severe VGE [Grade 3 or 4; Spencer Scale], and time to development of either severe VGE or DCS) indicated that exercise-enhanced prebreathe offered better protection than resting prebreathe under the conditions tested here. If the one-hour prebreathe with exercise continues to result in levels of DCS symptoms which are not significantly different from the 10.2 psia staged decompression, further research will be recommended with the goal of possibly substituting an exercise-enhanced prebreathe for the 10.2 psia staged decompression procedure. As shown in Figure 2, this substitution could reduce total prebreathe time and alleviate the need for decompression of the entire Shuttle.

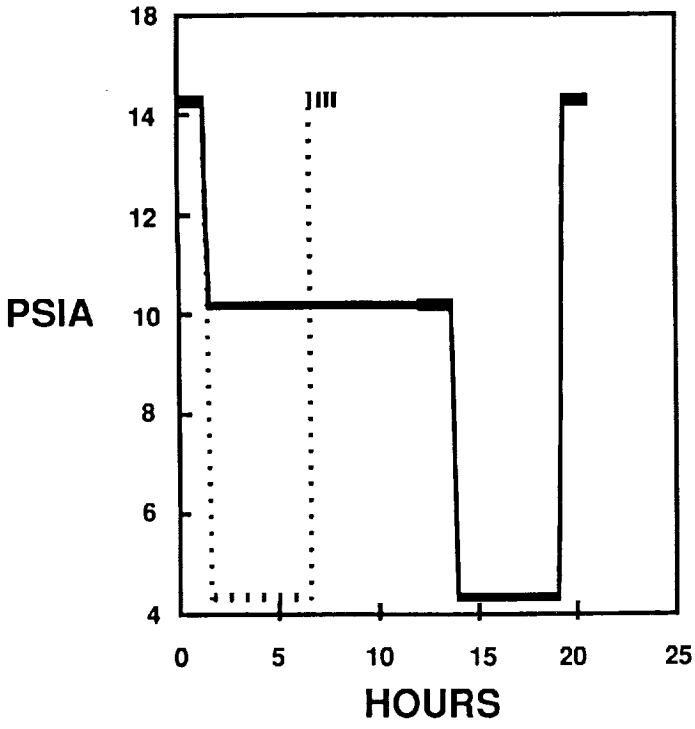

Figure 2: PREPARATION FOR A 6-HOUR EVA

CONCLUSION

A one-hour prebreathe beginning with 10 minutes of dual-cycle ergometry may offer protection from development of DCS symptoms which is comparable to either the current 10.2 psia staged decompression schedule or to 3.5 hours of resting prebreathe. Continued testing to complete the full complement of 26 subjects is underway to allow planned statistical comparisons.

ACKNOWLEDGMENTS

This research was sponsored in part by the Armstrong Laboratory, Brooks AFB, TX, USAF Contracts F-33615-89-C-0603 and F-33615-92-C-0018 and by NASA Contract T-82170. We appreciate the technical assistance of Ms. Heather O. Alexander and Ms. Donya K. Beene.

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